3.0 AIRBORNE EFFLUENT MONITORING

All airborne emissions from DOE-controlled facilities[a] *should** be evaluated and their potential for release of radionuclides assessed. This assessment is required to demonstrate that all such releases are adequately controlled and their environmental impacts properly evaluated. The potential for emissions *should** include consideration of the loss of emission controls while otherwise operating normally. The results of this evaluation also provide the basis for the site's effluent monitoring program (as discussed in DOE 5400.5), which *should** be documented in the site Environmental Monitoring Plan (as discussed in DOE 5400.1) to show

- Effluent monitoring (sampling or in situ measurement) extraction locations used for providing quantitative emission data for each emission point
- Procedures and equipment needed to perform the extraction and measurement
- Frequency and analyses required for each extraction (continuous monitoring and/or sampling) location
- Minimum detection level and accuracy
- Quality assurance components
- Investigation and alarm levels.

Airborne emissions from DOE-controlled facilities that have the potential for causing doses exceeding 0.1 mrem (effective dose equivalent) to a member of the public under realistic exposure conditions from emissions in a year *should** be monitored in accordance with the requirements of DOE 5400.1 and DOE 5400.5. As appropriate, component systems may be grouped and standard procedures referenced.

3.1 SUMMARY OF GENERAL CRITERIA AND MONITORING REQUIREMENTS

The criteria listed in Table 3-1 *should** be used to establish the airborne emission monitoring program for DOE-controlled sites. The criteria listed in Table 3-1 are based on the projected effective dose equivalent in one year to a member of the public (in mrem). Additional airborne emission requirements for DOE-controlled facilities that are required under DOE 5400.1 and DOE 5400.5 are given in the summary and discussed in this chapter. The monitoring effort *should* be commensurate with the importance of the sources during routine operation and from potential accidents with respect to their potential contribution to public dose or to contamination of the environment.

(a) DOE usage of the terms "site" and "facility" is considered equivalent to 40 CFR Part 61 usage of the terms "facility" and "source."

TABLE 3-1. Criteria for Emission Monitoring

Calculated Maximum Dose from Emissions in a Year to Members of the Public: H_E mrem [effective dose equivalent (EDE)]	Minimum Emission Monitoring Criteria[a]
$H_E \geq 1$	1) Continuously monitor emission points that could contribute ≥0.1 mrem in a year 2) Identify radionuclides that contribute ≥10% of the dose 3) Determine accuracy of results (±% accuracy and % confidence level) 4) Conduct a confirmatory environmental survey annually or Monitor at the receptor: 1) Continuously sample air at receptor 2) Collect and measure radionuclides contributing ≥1 mrem (EDE) above background 3) Establish sampler density sufficient to estimate dose to critical receptor given typical variability of meteorological conditions 4) Obtain prior approval from EPA
$0.1 < H_E < 1$	1) Continuously monitor emission points that could contribute ≥0.1 mrem in a year 2) Identify radionuclides that contribute 10% or more of the dose 3) Conduct confirmatory effluent monitoring at emission points where possible 4) Conduct a confirmatory environmental survey every few years
$H_E < 0.1$	1) Take periodic confirmatory measurements 2) Test to determine need to monitor by calculating dose (H_E) for normal operation, assuming that the emissions controls are inoperative 3) Conduct a confirmatory environmental survey at least every five years

(a) Permission for the use of alternative criteria may be obtained through EH, who will coordinate the request with EPA Headquarters to obtain EPA concurrence, where applicable. Coordination with EPA Regional Offices should be accomplished through DOE Program Office authority.

3.2 REQUIREMENTS FOR COMPLIANCE WITH EPA REGULATIONS

Airborne emissions of radioactive materials from DOE-controlled facilities are subject to the regulations of the U.S. Environmental Protection Agency (EPA). The primary regulation is 40 CFR Part 61, "National Emission Standards for Hazardous Air Pollutants" (NESHAP). The specific emission standard is contained in Subpart H of 40 CFR Part 61. Additional requirements that cover specific DOE-controlled operations are found in 40 CFR Part 192, regulating emissions from uranium and thorium mill tailings operations. For the purpose of compliance with the dose equivalent limits contained in 40 CFR Part 61, Subpart H, a "facility" is considered to be the entire site (e.g., Hanford Site, Savannah River Site, Idaho National Engineering Laboratory), including all of its potential "sources," or DOE-controlled facilities. Procedural requirements of 40 CFR Part 61, such as applications for approval to construct, also apply to individual DOE-controlled facilities within each site. Subpart H of 40 CFR Part 61 contains EPA-approved principles and methods by which airborne emissions are measured to demonstrate compliance with the emission standard.

3.3 PERFORMANCE STANDARDS FOR AIR-SAMPLING SYSTEMS

The frequency requirements for airborne emission monitoring (continuous monitoring and/or sampling) programs are summarized in Table 3-1. Application of these criteria to an individual facility (DOE-controlled site) or source (DOE-controlled facility) requires that an adequate study of the expected releases, potential exposure pathways, and resulting dose be conducted. For all new facilities or facilities that have been modified in a manner that could affect effluent release quantity or quality or that could affect the sensitivity of monitoring or surveillance systems, a preoperational assessment *should** be made and documented in the site Environmental Monitoring Plan to determine the types and quantities of airborne emissions to be expected from the facility, and to establish the associated airborne emission monitoring needs of the facility. The performance of the airborne emissions monitoring systems *should** be sufficient for determining whether the releases of radioactive materials are within the limits or requirements specified in DOE 5400.5. Sampling and monitoring systems *should** be calibrated before use and recalibrated any time they are subject to maintenance or modification that may affect equipment calibration. Sampling and monitoring systems *should** be recalibrated at least annually and routinely checked with known sources to determine that they are consistently functioning properly. Provisions for monitoring of airborne emissions during accident situations *should** be considered when determining routine airborne emission monitoring program needs.

3.3.1 Defining Point or Diffuse Sources

The sources (DOE-controlled facilities) contributing to the total emissions from a facility (DOE-controlled site) can be considered as either "point" sources or "diffuse" sources. A point source is a single defined point (origin) of an airborne release such as a vent or stack. A diffuse source is an area source or several sources of radioactive contaminants released into the atmosphere (generally, all sources other than point sources).

3.3.2 Diffuse Sources

The category of diffuse sources covers many situations, most of which are difficult to characterize (e.g., ponds, contaminated areas, structures without ventilation or with ventilation that does not result in a well-defined release point). Attempts to define the emissions under such an array of conditions and other complex and ill-defined factors affecting the transport of the emissions (generally meteorological and topographical factors) would require complex sampling techniques, and repositioning of equipment may be necessary. Diffuse sources *should** be identified and assessed for their potential to contribute to public dose and *should** be considered in designing the site effluent monitoring and environmental surveillance program. Diffuse sources that may contribute a significant fraction (e.g., 10%) of the dose to members of the public resulting from site operations *should** be identified, assessed, documented, and verified annually.

3.3.3 Diffuse Source Assessment

If a diffuse source assessment is warranted because of potential contribution to the offsite dose, the following procedures *should* be applied:

1) The assessment *should* be accomplished by using appropriate computational models and/or a downwind array of samplers arranged and operated over a sufficient period to characterize the concentrations of radionuclides in any resulting plume.

2) Empirical data and sound assumptions *should* be used with the computational models to define the source term for a diffuse source.

The validity of the resulting release estimates relies on the professional judgment and knowledge of the individuals involved and is usually difficult to verify. As a general rule, reliance will be placed on the site environmental surveillance program to confirm predictions.

3.4 DESIGN CRITERIA FOR SYSTEM COMPONENTS

Airborne emission sampling and monitoring systems *should** demonstrate that quantification of airborne emissions is timely, representative, and adequately sensitive. The design of such systems begins with a characterization and documentation of the emission sources. The level of detail required *should* be sufficient to provide that the system is qualified for the task. A number of factors are critical to this characterization, but their importance can vary in a specific situation. The following factors are among those that *should* be considered:

- Identification of the actual or potential radionuclides present (e.g., type, concentration)

- Identification of fallout and naturally occurring (background) radionuclides

- Presence of materials (chemical, biological) that could adversely affect the sampling and monitoring system or detection of radionuclides

- Internal and external conditions that could have a deleterious effect upon the quantification of emissions (e.g., environmental factors such as temperature, humidity, and ambient ionizing radiation; events that could result in a complete loss of the systems, such as fires, floods, or earthquakes; and gas-stream characteristics, such as temperature, pressure, humidity, and velocity)

- Process descriptions and variability

- Particle-size distribution of particulate materials

- Cross-sectional homogeneity of radionuclide distribution at the sampling point.

Additional information on factors that influence sampling systems and aerosol behavior can be found in Hinds (1982) and Hidy (1984). For most DOE operations, effluents are assumed to be emitted to the ambient atmosphere under two physical configurations - point and diffuse sources.

3.4.1 Point Sources

For point sources, documentation of the important characteristics of the exhaust handling system and other pertinent structural information, the pertinent characteristics of the process and process-emission control systems, and the sampling and measurement systems *should* be included in the site Environmental Monitoring Plan. Any reports or data from studies conducted to evaluate the operational performance or real or suspected deficiencies of the systems *should* also be provided at a single, readily accessible location (e.g., the site airborne emission monitoring files).

3.4.2 Diffuse Sources

The types of information to be documented in the site Environmental Monitoring Plan for diffuse sources are less readily identifiable. Diffuse sources can range from large areas of contaminated soil to ponds or uncontrolled releases from openings in a structure. The factors that have a significant influence on the air suspension of radionuclides from these situations depend on the force applied (which results in suspension of the radionuclide in air) and the factors that resist suspension [e.g., subdivision of liquid surface by shear stress (sprays) from ambient winds, over-pressure phenomena within a structure that result in the atmospheric release of radionuclides, the exchange of indoor and outdoor atmospheres at portals, and aerodynamic entrainment of contaminated soil]. A potential source *should* be adequately described to show the radionuclides present, the form of the materials, and the factors contributing to suspension. The rationale to substantiate the approach used to assess and characterize the source *should* be documented. Information on considerations in diffuse-source sampling can be found in Hesketh and Cross (1983). The most reliable source of data is likely to be local experience with similar installations. In addition to the discussions of input parameters in documentation supporting the EPA/CAP-88 and AIRDOS computer codes, additional insight into the parameters necessary for estimating dose from fugitive emissions is provided by Whelan et al. (1987), Gilbert et al. 1989, and EPA-600/12-87-066.

3.4.3 Gases and Vapors Versus Particulates

Radionuclides in gaseous effluents can be in the form of noncondensable gases, vapors, and particulate materials. The design criteria for gases and vapors (considered to have the same flow behavior) can be less rigorous than those required for sampling particulate materials, since the inertial forces that affect the distribution of particles in a gas stream are much less important. Where criteria or requirements have not been specified in this section, guidance is provided to aid users in designing and operating air-sampling systems.

3.5 POINT-SOURCE DESIGN CRITERIA

3.5.1 Gas-Stream Characterization Methods

Accepted methods [C 3154-72, 3195-73, D 3464-75, D 3796-79 (ASTM 1985); EPA Method 1 (Smith 1984)] *should* be used to measure gas-stream characteristics (e.g., velocity, static pressure, temperature, and moisture content) consistent with sampling conditions. The characteristics and conditions of gas flow can vary widely, and the frequency of the measurements needed to meet the required accuracy for flow-rate determination will be based on the stability of flow from that source (DOE facility), the impact of the gas characteristic on the sample taken, and the significance of the contribution from that source (DOE facility) to the radiological impact of the emissions from the facility (DOE site). EPA Methods 1, 2, and 4 *should* be used to measure and determine stack velocity, static pressure, temperature, and moisture content. EPA Method 1 determines where and how many velocity measurements must be taken. EPA Method 2 is the actual procedure used to measure and determine stack gas velocity, static pressure, and volumetric flow rate. EPA Method 4 is used to determine moisture content in stack gases.

3.5.2 Location of Sample-Extraction Sites

Samples of gaseous effluents *should* be extracted from an accessible location in the stack downstream from any obstruction, preferably near the outlet, so that concentrations of the material of concern are uniform. To the extent practicable, samples *should** be extracted from the effluents from a location and in a manner that provides a representative sample, using multiport probes if necessary. If feasible, gaseous effluents *should* be extracted at least eight stack or duct diameters downstream and two stack or duct diameters upstream from any major flow disturbances (e.g., bends, transitions, open flames, last stream entry, sampling probes, etc.) (EPA Method 1, Smith 1984). The extraction point *should* be as close as practicable to the point where the emissions from that source (DOE facility) are released to the atmosphere while still complying with the criteria defined above. If possible while meeting the mixing length requirement, extraction sites *should* be located in vertical sections of the stack or duct. The absence of cyclonic flow at the extraction site *should* be demonstrated (EPA Method 1, Smith 1984). EPA Method 1 states that in no case will sample extraction sites be located less than two (2) stack diameters downstream and one-half (0.5) stack diameter upstream from any flow disturbance, unless approved by EPA. If uniform flow and concentration can be demonstrated at a stack or duct location during all anticipated operating conditions, a single probe with the average velocity of the effluent flow integrated over the cross section of the probe opening can be used (ANSI N13.1-1969). If uniform flow and concentration cannot be demonstrated or if incomplete mixing is suspected in large-diameter stacks or ducts (diameters greater than 30 cm), the need for multiple inlet probes under continuous sampling conditions *should* be considered. If multiple inlet probes are used, the volume flow through each inlet *should* be proportional to the volume fraction of the effluent flow in the annular area sampled.

3.5.3 Sample-Extraction Probes

Requirements for the sampling of gases and vapor depend on the presence of particulate material. If the material of concern exists as a gas or vapor that does not interact with particulate material in the gaseous effluent, simply extracting a known fraction of the effluent flow is adequate provided the criteria for uniform flow and concentration are met. Such conditions are not the norm; many vapors (e.g., radioiodine) interact with existing particles, and all materials *should* be collected so that quantification of emissions is accurate.

Extraction probes and nozzles for the sampling of particulate materials *should* be consistent with ANSI N13.1-1969 and EPA Method 5 (Smith 1984) for particulate materials. These referenced standards/methods are also recommended as general guidance for the sampling of gases and vapors. Probes for aerosol sampling *should* be positioned isoaxially in the stack or duct and sized to extract at the same velocity as the effluent stream sampled (isokinetic sampling) when particle mass median diameter exceeds 0.5 μm. Although it is believed that isokinetic sampling conditions are not required to extract aerosols that have passed through a properly operating high-efficiency particulate filter system (because of the removal of large-diameter airborne particulate material), it is good practice to provide isokinetic sampling conditions to the extent practicable and to consider transport under moderate turbulence conditions to minimize the loss of any particulate materials present.

Probe nozzles for the sampling of aerosols *should* be constructed of seamless stainless-steel tubing (or, for corrosive atmospheres, other rigid, seamless tubing that will not degrade under sampling conditions) with sharp, tapered edges. The angle of taper *should* be 30°, and the taper *should* be on the outside edge to preserve a constant internal diameter (EPA Method 5, Smith 1984). Probes *should* be designed so that they can be easily removed for cleaning, repair/replacement, or deposition evaluation. Changes in flow direction *should* be made with bends having a curvature radius of at least five tube diameters (ANSI N13.1-1969) to accommodate the diameter of the largest particle in the sample. Probe nozzles for the sampling of only gases and vapors *should* be constructed of corrosion-resistant materials that do not react to any significant degree with the materials collected. The nozzles *should* be rigid to the point of collection, accumulation, or measurement. If aerosol samples are extracted from more than one location in the stack/duct, all individual nozzles *should* provide isokinetic sampling conditions (ANSI N13.1-1969). Each individual nozzle *should* be designed to extract a proportionate volume of the sample.

3.5.4 Sample-Transport Lines

Where the material(s) of concern is in particulate form, gaseous effluent samples *should* be transported in lines that comply with ANSI N13.1-1969. If the material(s) of concern is in the form of gas(es) or vapor(s), the samples of gaseous effluents *should* be transported in lines with no significant leakage or loss of material (by chemical reaction, condensation, etc.). For consistency with EPA Method 5, significant leakage is any leakage rate in excess of either 4% of the average sampling rate or 0.02 cfm, whichever is less. Lines *should* be kept as short as possible. Sample lines *should* be constructed of conducting material only. Systems that directly expose the collector or monitor to the effluent stream are preferred. Line diameter and materials of construction *should* be selected to minimize wall losses under anticipated sampling conditions. Aerosol transport lines *should* be rigid and *should* be electrically grounded to the point where the particles are collected/accumulated. Aerosol transport lines *should* not have sharp bends. Changes in direction *should* be made with radii of curvatures greater than five tube diameters. The transport lines *should* be adequately supported to prevent sagging and undue stress. Transport lines *should* be made of materials resistant to corrosion under anticipated sampling conditions and *should*, as required by ambient temperature, be insulated and/or trace-heated to prevent condensation of materials under anticipated sampling conditions.

3.5.5 Air-Moving Systems

Air-moving systems for gaseous effluent sampling *should* be constant displacement systems (e.g., rotary vane, gear) or other systems that will maintain constant air flow in anticipated sampling conditions. A central vacuum system with a vacuum pump and receiver large enough to provide simultaneous flow for all samplers may be used in situations where sampling from many locations is anticipated. Pumps and other mechanical components *should* be designed to operate continuously under anticipated operating conditions, with scheduled preventive maintenance and repair. Equipment used for intermittent or grab sampling *should* be designed to operate continuously for the duration of the sampling period(s).

3.5.6 Air-Flow Measurements

Sampler gas flows *should* be continuously measured and measurements recorded over the duration of the sampling period. The period over which measurements are integrated and the frequency of the recording *should* be determined by the significance of the emission being measured and the anticipated flow fluctuations. All sampling systems *should*, at a minimum, have a gas-flow gage that is read and recorded daily, unless it can be demonstrated that the flow rate is constant, and at the start and end of each sampling period. Unless extenuating circumstances dictate otherwise, the flow measurements *should* be accurate to ±10% by calibration with standards traceable to the National Institute of Standards and Technology (NIST) (DOE/EP-0096). The most frequently used devices for these measurements are rotameters. Venturi meters, fixed orifices, vane anemometers, and Pitot tubes may be used within their limitations (ANSI N13.1-1969). Other devices, such as hot-wire anemometers, can also be applied within their limitations, but all devices *should* be calibrated under conditions of anticipated use with NIST-traceable or equally acceptable (in the case where an NIST standard does not exist) standards. Flow-measuring devices used for compliance determinations *should* be located downstream from the collector since deposition, condensation, and corrosion can result in erroneous measurements. The main objective of accurate effluent flow measurement is to allow accurate estimates of radionuclides in the effluent. Knowledge of the fraction is important for the maintenance of isokinetics. Performance standards and design criteria for the measurement and control of the bulk effluent flows (i.e., flow in the process effluent stream) *should* be consistent with the requirements for sampling flow measurement and control. Because the intent is to extract a known fraction of the gaseous effluent being sampled, accurate and reliable measurement of the effluent flow is also important. Normally, automatic air-flow feedback systems that adjust sampler flow, which is induced by the monitoring-system sampling pump, by continuously measuring effluent flow to maintain isokinetic sampling conditions will not be required. The need for feedback systems *should* be considered for each emission stream having large fluctuations in flow (greater than a factor of two) and contributing a major fraction (e.g., greater than 10%) of the offsite emission limit for radionuclides from the facility.

3.5.7 Sample Collectors

The design and capabilities of the collector will depend on the form of the radionuclides to be collected, the sampling conditions, and the analytical techniques to be used. The radionuclides in gaseous effluents can be found in all three physical forms - gases, vapors, and particulate materials. Different techniques are needed to collect and separate the physical forms or individual chemical compounds within the forms. ANSI N13.1-1969 *should* be followed to the extent practicable. Because the intent of sampling and measurement is to provide accurate, reliable quantification of radionuclide emissions, collectors with the most reproducible collection efficiency under anticipated sampling conditions *should* be used. Collector housing and hardware *should* be designed to minimize sample loss.

3.5.8 Continuous Monitoring Systems

Timeliness *should* be considered when quantifying radionuclides in gaseous effluents. Where the potential offsite radiological impacts are well below the standard, radionuclide sampling and collection with periodic measurement (e.g., laboratory analysis) are sufficient to quantify the radionuclides. However, where a significant potential (greater than once per year) exists for approaching or exceeding a large fraction of the emission standard (e.g., 20%), continuous monitoring *should** be required. System specifications require a careful balancing of sensitivity, energy response. response time, and accuracy for the radionuclide of interest [ANSI N42.18-1974 (R 1980)]. The electrical and electronic factors to be considered are covered in IEC N. 761-1. Continuous monitoring systems range from a simple ionization chamber to a system that monitors and records a spectrum of radionuclides (e.g., flow-through ionization chambers preceded by absolute filters and iodine removal systems). Compensation or adjustment *should* be provided for pressure, temperature, humidity, and external background. To interpret the measurements correctly, the composition of any noble gases present must be known. If significant amounts of tritium are present, tritium removal is necessary before other measurements are taken. Monitors using a stainless-steel vessel with a known volume of gas and a lithium-drifted germanium detector [Ge(Li)] or an intrinsic germanium detector or equivalent *should* be used (DOE/EP-0096). Monitoring can be performed by either in-line or off-line systems. In-line systems are those in which the detector assembly is immersed in the effluent stream, usually in a well or other protection, while off-line systems pull an aliquot from the effluent stream for collection or conveyance to a detector assembly. In-line systems are less complex than off-line systems but may not provide specific radionuclide measurements directly (DOE/EP-0096). In certain types of facilities (e.g., chemical separations plants), a representative sample may require dehumidification and reheating before distribution to separate monitors for specific measurements (e.g., alpha, beta, gamma spectroscopy, radioiodines, krypton). Specifications that *should* be considered for airborne emission monitoring systems are as follows (other guidance may be found in DOE/EP-0096).

3.5.8.1 <u>In-line and Off-line System Specifications</u>

- Meet all design criteria for air sampling except those for air sample transport.
- Have calibrated curves for the detector assembly that allow conversion of instrument signals to release rates from which both the current concentrations and the total specific radionuclide emissions can be estimated.
- Have only the detectors and small electronic assemblies located in or adjacent to the effluent stream (IEC N. 761-3). A detector *should* not be particularly sensitive to environmental conditions or require frequent attention or adjustment.
- Use appropriate calibrations for radionuclides to be measured, including ratios to other nonmeasurable radionuclides, if present.
- Meet performance requirements within the anticipated environmental conditions (e.g., temperature, humidity, radiation levels). Systems to control the environment for the proper functioning of the monitors *should* be provided.
- Have adequate access for maintenance, repair, and calibration.
- Have a stable source of electrical power.

3.5.8.2 Special Housing

Special housing may be necessary to meet these specifications. In either case, the available signal range *should* include the full range of operating conditions. The signal range of routine effluent monitoring systems that are also identified for use during accidents *should* be sufficient to monitor releases from design basis accidents. If a measuring cell or gas chamber is used to provide a known volume of gas for measurement with an immersed or adjacent detector, the following design features *should* be considered:

- A flow-through type vessel or chamber with or without absorbing medium or pressurization

- Specifications for cell volume and pressure

- Separation of the detector from the sample by a protective screen if practicable

- A readily removable detector mounted so that it will be returned to and maintained in its original position, and provision for an alternate position or other means of varying response by a factor of at least 10.

3.5.8.3 Specific Radionuclide Monitors

The following criteria are guidelines to be considered for monitors that measure specific radionuclides.

Tritium Monitors. ANSI N42.18-1974 (R 1980) specifies a minimum level of detectability (MLD) for tritium of 5×10^{-6} μCi/mL for continuous monitors used in gaseous effluent streams. IEC N.761-5 specifies a minimum level of detectability of 2×10^{-6} μCi/mL. The ANSI MLD is a 1974 minimum standard, and it specifies measurable concentrations at a 95% confidence level after 4 hours of sample collection. However, the detectability level may not be obtainable with mixtures of radionuclides, and instrument response is limited by natural airborne radioactive materials (radon and thoron in equilibrium with their decay products). Additional concerns that *should* be considered in instrument design for tritium monitors based on the IEC standard (IEC N.761-5) are as follows:

- Temperature control during sample transport to prevent condensation (much of the tritium may be in the form of airborne water vapor); and

- Trapping or retention of water by a filter or sorbent (since much tritium is commonly in the form of HTO).

Ionization Chambers. These chambers are widely used for measuring gaseous tritium (DOE/EP-0096). They are simple and economical. A useful rule-of-thumb for measuring tritium in air with ionization chambers is that ionization current collected at saturation is approximately 1 μA/Ci. Tritium measurements of about 10^{-5} μCi/mL are possible in low-background environments, which produce ions at a rate equivalent to 1 mrem/hour. Shielding may be required for specific applications. If shielding is not practical, a second chamber exposed to the same gamma field without tritium is recommended. Changes in pressure and temperature in the chamber can affect the calibration, and appropriate adjustment controls for these factors *should* be provided. Ionization chambers are more sensitive to radioactive (noble) gases that produce larger energies per disintegration and may cause major interferences. Proportional counters are also used to measure airborne tritium (DOE/EP-0096). They are relatively insensitive to background radiation and have energy discrimination capabilities. Systems using proportional counters are more complicated than those required for ionization chambers. Proportional counters require a counting gas, and many gases are flammable or combustible. Radioactive material present in natural products (e.g., commercial natural gas) may provide interference for tritium measurements and *should* be accounted for if used. Air can be added to methane up to 30% by volume at a dewpoint of 14°C without truncating the counting plateau to unacceptable levels. Dry air may be required where tritium exists as water vapor. The high voltage *should* be stabilized by feedback from a known source for unattended operations.

Radioiodine Monitors. Iodine cartridges used to collect radioiodine may be monitored at the collection point with a shielded detector, usually a single-channel thallium-activated sodium iodide [NaI(Tl)] detector. Typical systems have one or more charcoal cartridges in a series, preceded by an absolute particulate filter. In-line measurements of low concentrations of radioiodine in air will usually not be feasible because of the presence of other radionuclides or radiation fields. Iodine cartridges must be replaced at least weekly and the measurements verified by laboratory counting (DOE/EP-0096). Minimum levels of detectability for various iodine isotopes for continuous monitors of gaseous effluents must be established for a site, considering current state-of-the-art monitoring capabilities. The same general specifications given in the preceding discussion of tritium monitors, based on the IEC standard, *should* be considered for iodine monitors. Specifications for iodine monitors are as follows:

- Protection of the detector head from contamination (by the gaseous medium) by an interchangeable thin screen; easy removal of supplemental devices such as temperature sensors, heaters, etc., in the inlet for decontamination; and use of construction materials that are easily decontaminated or are contamination resistant.

- Design of collection assembly and detector to minimize the holdup of gases.

- Determination of the characteristics (e.g., collection efficiency, retention capacity, delay-time constants) for all media in the collection train (solid sorbent, absolute particulate filter) for various radioactive gases of significance in the gaseous effluents, including radon and thoron.

- Design of systems such that replacement of sorbent and filter *should** not disturb the geometry between the collector and detectors.

Noble Gas Monitors. The lower level of detectability specified for noble gas monitors for gaseous effluents listed in ANSI N42.18-1974 (R 1980) ranges from 5×10^{-6} μCi/mL to 2×10^{-7} μCi/mL. MDLs must be established for a site, considering current state-of-the-art field-monitoring capabilities. Flow-through ionization chambers or proportional counters may be used. Usable signals from noble gas monitors depend on adequate removal of other radionuclides from the sample stream.

3.5.8.4 Particulate Monitors (General)

The lower level of detectability specified in ANSI N42.18-1974 (R 1980) for radionuclides that could exist in particulate form ranges from 4×10^{-7} μCi/mL for ^{54}Mn to 2×10^{-12} μCi/mL for many of the heavy metals. Minimum detection levels must be established for a site, considering current state-of-the-art monitoring capabilities. IEC N. 761-4 addresses aerosol effluent monitors. Aerosols are defined as suspensions of fine solid or liquid particles generally in the range of 0.01 μm to a few tenths of a micrometer in diameter. The standard considers gross alpha and gross beta monitors.

The following instrument characteristics described in the standard *should* be considered:

- The total equivalent window thickness (mg/cm^2) that an ionizing particle normally emitted from the surface of the collected aerosol will cross to reach the sensitive area of the detector (includes distance covered in air plus the window thickness and that of any thin, protective screen)

- The best estimate of the surface emission rate determined from a primary or secondary standard or by reference to an instrument that has been calibrated against a primary or secondary standard

- A check source, supplied with the monitor, designed to be used in place of the filter in the retention device

- A protective cover over the detector that can be easily exchanged from the front of the detector or designed to facilitate decontamination of the detector head

- The general monitor concerns for sampling and exhaust piping for tritium monitors

- For alpha monitors, filters that retain the particles on the surface

- A filter holder that facilitates decontamination, considers the mechanical strength of the filter medium use and pump characteristics, and minimizes wall deposition

- Avoidance of gross nonuniform particle deposition
- A detector assembly that minimizes the volume of a sample which may affect the response of the detector
- A filter holder design that minimizes in-leakage and internal leakage around the filter
- A filter holder design that permits fast and easy removal
- A useful detector area approximately equal to that of the particle collecting surface
- A total equivalent window thickness that is less than 2 mg/cm^2 for alpha monitors and is appropriate for the beta spectrum anticipated for beta monitors.

The following methods of discrimination against natural background radiation (radon, thoron, and their decay products) are specified by the standard:

- Delayed measurements after suitable decay of natural radionuclides
- Energy spectrum analysis (primarily with alpha monitors)
- Use of other physical properties of natural radionuclides (e.g., pseudo-coincidence, particle-size selection)
- Electronic compensation.

DOE/EP-0096 provides additional guidance for specific types of aerosol monitors - alpha-emitting transuranics (plutonium), uranium, and other particulates. For plutonium, the usual counting methods determine a gross alpha activity with application of an independent determination of isotopic content.

3.5.8.5 Transuranic (TRU) Radionuclide Monitors

ANSI N317-1980 covers "performance criteria for instruments used for inplant plutonium monitors." Much of the standard addresses contamination survey instrumentation and specifically does not include "personnel dosimeters, effluent monitoring systems, or instruments needed in bioassay programs." ANSI N317-1980 also does not "define those requirements which may be needed to monitor emergency conditions."

Fixed Monitoring Instruments. Section 5.2 of ANSI N317-1980 addresses fixed monitoring instruments [i.e., continuous air monitors (CAMS)], which are also used as gaseous effluent monitors. These instruments can be used for monitoring TRU emissions. The following specifications must be considered:

- The establishment of a minimum detection level, based on current state-of-the-art field-monitoring capabilities

- An operating range of at least 100 times the minimum detectable levels

- A maximum error of ±20% over the upper 80% of its operating range

- The measurement repeatability within ±10% at the 95% confidence level for the midscale or mid-decade reading

- A response time less than that required to maintain background readings within required accuracy

- Continuous operation within the specified accuracy in relative humidities of 40% to 95%

- Less than 5% change in calibration with continuous operation at ambient pressure and temperature

- Voltage and frequency variations of ±15% of design values resulting in reading variations of less than 5%

- Insensitivity to radio-frequency microwaves associated with power-line noise suppression

- Batteries capable of supplying power for 18 hours of normal operations, or 2 hours under alarm conditions

- A sample transport line designed to meet the requirements of ANSI N13.1-1969 through primary calibration at least once with NIST-traceable standards.

Transuranic Aerosol Effluent Monitor Design. The IEC[a] draft standard specifically addresses transuranic aerosol effluent monitors. Window thickness is defined in the same manner as for the aerosol effluent monitors. Collection efficiency is defined as the ratio of concentration represented by the collection media to the concentration in air sampled. Two types of monitors are covered - alpha spectrometers and gross-alpha monitors. The specifications in the IEC draft standard that *should* be considered are

- Provide check sources; design to allow the check source to be held in the retention device in place of the filter or collection medium.

- Protect the detector assembly or design for easy exchange or decontamination.

(a) International Electrochemical Commission. 1985 (Draft). "Specific Requirements for Transuranic Aerosol Effluent Monitors." In Equipment for Continuously Monitoring Radioactivity in Gaseous Effluents, Part C. 45B (Central Office) 67, International Electrotechnical Commission, Geneva, Switzerland.

- Extract under isokinetic conditions; design sample transport lines and collection device to prevent particle loss.

- Hold the sample flow rate to ±10% specified air flow with an error no greater than ±10% of total air volume sampled.

- Collect by filtration or impaction: select collection medium that minimizes absorption of alpha radiation by the collection medium.

- Design the filter holder on the mechanical strength of the filter and the collection rate needed to achieve the required detection levels; filters may be circular, square, or rectangular.

- Design the monitor to minimize leaks, particularly internal leaks, allowing flow to bypass the collection medium.

- Design the monitor to allow rapid, easy removal of the collection medium without significant risk of damage to the detector.

- Design the monitor to allow complementary laboratory analysis of the collection media.

- Assess the collection efficiency of the retention device over the range of 0.01 to 10.0 μm aerodynamic equivalent diameter under normal conditions of proposed use.

- Assess detector characteristics (e.g., effective area, maximum total equivalent window thickness, protective coating, variation in detector efficiency as a function of energy).

- For alpha spectrometers, determine the full width at one-half maximum energy resolution of the detector to the alpha energy spectrum of interest under specific background radiation levels.

- Design monitors to prevent effects of noxious chemicals and water vapor.

The standard also specifies three acceptable methods of discrimination against natural background radiation:

- Alpha spectroscopy

- Reduction of interfering radon-thoron decay products by use of impaction

- Delayed measurement.

3.5.8.6 Uranium Monitors

The continuous strip filter counters with combined alpha and beta counting ratios can be considered if uranium is the only particulate radionuclide present. Gamma spectroscopy is suggested for consideration at high concentrations. DOE/EP-0096 can provide further guidance.

3.5.8.7 Particulate Fission and Activation Product Monitors

Other radionuclides in the form of particulate materials are commonly monitored by collection on filters and counted for gross beta activity if the identities and ratios of radionuclides are known (DOE/EP-0096). Shielded beta detectors are considerably more practical than gamma detectors, and most gamma emitters also emit beta radiation. If measurements of specific, gamma-emitting radionuclides are required, NaI(Tl), lithium-drifted germanium [Ge(Li)], or intrinsic germanium detectors *should* be used.

3.6 ALARM LEVELS

To signal the need for corrective actions that may be necessary to prevent public or environmental exposures from exceeding the limits or recommendations given in DOE 5400.5, when continuous monitoring systems (as required by the criteria in Table 3-1) are required, they *should** have alarms set to provide timely warnings. Gaseous effluents from DOE facilities are predominantly from point sources. Often the effluent is treated to control the emissions of radionuclides to near-background levels of naturally occurring airborne radionuclides. However, the cumulative effect of many low-level releases may result in impact near the criteria for continuous emission monitoring. Emission sampling is only part of the overall protection system at DOE facilities. Environmental sampling and monitoring provide an additional level of measurement so that any such releases are detected.

3.7 QUALITY ASSURANCE

As they apply to the monitoring of airborne emissions, the general quality assurance program provisions discussed in Chapter 10 *should** be followed. Specific quality assurance requirements for the facility's airborne emission monitoring program are to be contained in the Quality Assurance Plan associated with the facility.